WHAT IS CLAIMED IS:

1. A metal oxide-containing composition, the composition comprising:

metal oxide nanoparticles described on average by Formula I:

M_xO_y I ; and

one or more heteroatom donor ligands bonded to the surface of the nanoparticles,

wherein

M is a metal;

O is oxygen; and

x and y are numbers having a ratio that is equal to the ratio of the average number of M atoms to the average number of O atoms in the nanoparticles, wherein the number of M atom is from about 10 to about $5x10^{10}$ atoms and the number of O atoms is at least about 0.01 times the number of M atoms.

2. The metal oxide- containing composition of claim 1 wherein M is a metal selected from beryllium, magnesium, aluminum, scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, gallium, germanium, yttrium, zirconium, niobium, molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, indium, tin, antimony, lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, hafnium, tantalum, tungsten, rhenium, osmium, iridium, platinum, gold, thallium, lead, bismuth, polonium, thorium, protactinium, uranium, neptunium, and plutonium.

3. The metal oxide- containing composition of claim 1 wherein M is a metal selected from Group 9 through Group 11 elements.

4. The metal oxide- containing composition of claim 1 wherein the one or more heteroatom donor ligands include compounds containing an oxygen or nitrogen atom that are capable of acting as an electron-pair donor to form a bond to the surface of the nanoparticles.

5. The metal oxide-containing composition of claim 1 wherein the one or more heteroatom donor ligands are selected from the group consisting of alkyl amines, pyridine, 2,2'-bipyridine, pyrrole, pyrazole, imidazole, triazole, tetrazole, nitriles, carboxylic acids, carbonates, nitrates, nitroalkanes, nitroarenes, hydroxamic acids, ketones, aldehydes, and esters.

6. The metal oxide- containing composition of claim 1 wherein the nanoparticles have a mean diameter from about 1 nm to 1000 nm.

7. The metal oxide- containing composition of claim 1 wherein the nanoparticles have a mean diameter from about 1 nm to 100 nm.

8. The metal oxide-containing composition of claim 1 wherein the nanoparticles have a mean diameter less than about 20 nm.

9. The metal oxide-containing composition of claim 1 wherein the nanoparticles have a spherical, ellipsoidal, rod-shaped, or polyhedral morphology.

10. The metal oxide-containing composition of claim 1 wherein the metal oxide nanoparticles include amorphous or crystalline domains.

11. The metal oxide-containing composition of claim 1 wherein the nanoparticles include a mixture of metal atoms in different oxidation states.

12. The metal oxide-containing composition of claim 10 wherein the different oxidation states are one or more of the values selected from 0, +1, +2, +3, +4, +5, +6, +7, and +8.

13. The metal oxide-containing composition of claim 1 further comprising one or more loosely bound heteroatom ligands.

14. The metal oxide-containing composition of claim 13 wherein the one or more loosely bound heteroatom ligands are nitrate, halide, phosphate, perchlorate, formate, acetate, borate, hydroxide, silicate, carbonate, sulfite, sulfate, nitrite, phosphite, water, alkyl amines, pyridine, 2,2'-bipyridine, pyrrole, pyrazole, imidazole, triazole, tetrazole, nitriles, carboxylic acids, carbonates, nitrates, nitroalkanes, nitroarenes, hydroxamic acids, ketones, aldehydes, esters or mixtures thereof.

15. A metal oxide-containing solution, the solution comprising:
a solvent;
metal oxide nanoparticles described on average by Formula I:

M_xO_y I ; and

one or more heteroatom donor ligands bonded to the surface of the nanoparticles,
wherein
M is a metal;
O is oxygen; and
x and y are numbers having a ratio that is equal to the ratio of the average number of M atoms to the average number of O atoms in the nanoparticles, wherein the number of M atom is from about 10 to about $5x10^{10}$ atoms and the number of O atoms is at least about 0.01 times the number of M atoms.

16. The metal oxide-containing solution of claim 15 wherein the heteroatom donor ligand is derived from decanoic acid and the solvent is hexane.

17. The metal oxide-containing solution of claim 15 wherein the heteroatom donor ligand is 2,2'-bipyridine and the solvent is a polar solvent.

18. The metal oxide-containing solution of claim 15 wherein the solvent comprises at least one compound selected from the group consisting of methanol, ethanol, 1-propanol, isopropanol, 1-butanol, acetone, dichloromethane, and ethylene glycol.

19. The metal oxide-containing solution of claim 15 wherein the heteroatom donor ligand is 2,2'-bipyridine to which long chain alkyls have been attached and the solvent is a nonpolar solvent.

20. A method of applying metal oxide-containing nanoparticles to a substrate, the method comprising:

1) contacting the substrate with the solution of claim 15; and

2) evaporating the solvent or allowing the solvent to evaporate.

21. The method of claim 20 further comprising:

3) heating the metal oxide-containing nanoparticles at a sufficiently high temperature to form zero-valent metal.

22. The method of claim 21 wherein the metal oxide nanoparticles are heated to a temperature of at least 200 °C.

23. The method of claim 20 further comprising contacting the metal oxide nanoparticles with a reducing agent.

24. The method of claim 23 wherein the reducing agent is selected from the group consisting of molecular hydrogen, alcohols, amines, or mixtures thereof.

25. A copper oxide-containing composition, the composition comprising:

copper oxide nanoparticles described on average by Formula I:

Cu_xO_y II ; and

one or more heteroatom donor ligands bonded to the surface of the nanoparticles,

wherein

Cu is copper;

O is oxygen; and

x and y are numbers having a ratio that is equal to the ratio of the average number of Cu atoms to the average number of O atoms in the nanoparticles, wherein the number of Cu atoms is from about 10 to about $5x10^{10}$ atoms and the number of O atoms is at least about 0.01 times the number of Cu atoms.

26. The copper oxide- containing composition of claim 25 wherein the one or more heteroatom donor ligands include compounds containing an oxygen or nitrogen atom that is capable of acting as an electron-pair donor to form a bond to the surface of the nanoparticles.

27. The copper oxide-containing composition of claim 25 wherein the one or more heteroatom donor ligands are selected from the group consisting of alkyl amines, pyridine, 2,2'-bipyridine, pyrrole, pyrazole, imidazole, triazole, tetrazole, nitriles, carboxylic acids, carbonates, nitrates, nitroalkanes, nitroarenes, hydroxamic acids, ketones, aldehydes, and esters.

28. The copper oxide- containing composition of claim 25 wherein the nanoparticles have an mean diameter from about 1 nm to 1000 nm.

29. The copper oxide- containing composition of claim 25 wherein the nanoparticles have an mean diameter from about 1 nm to 100 nm.

30. The copper oxide-containing composition of claim 25 wherein the nanoparticles have an mean diameter less than about 20 nm.

31. The copper oxide-containing composition of claim 25 wherein the nanoparticles have a spherical, ellipsoidal, rod-shaped, or polyhedral morphology.

32. The copper oxide-containing composition of claim 25 wherein the copper oxide nanoparticles are amorphous or crystalline.

33. The copper oxide-containing composition of claim25 wherein the nanoparticles include a mixture of copper atoms in different oxidation states.

34. The copper oxide-containing composition of claim 32 wherein the different oxidation states are 0, +1, and +2.

35. The copper oxide-containing composition of claim 25 further comprising one or more loosely bound heteroatom ligands.

36. The copper oxide-containing composition of claim 35 wherein the one or more additional heteroatom containing molecules are nitrate, halide, phosphate, perchlorate, formate, acetate, borate, hydroxide, silicate, carbonate, sulfite, sulfate, nitrite, phosphite, water, alkyl amines, pyridine, 2,2'-bipyridine, pyrrole, pyrazole, imidazole, triazole, tetrazole, nitriles, carboxylic acids, carbonates, nitrates, nitroalkanes, nitroarenes, hydroxamic acids, ketones, aldehydes, esters, or mixtures thereof.

37. A copper oxide-containing solution, the solution comprising:
copper oxide nanoparticles described on average by Formula I:

Cu_xO_y II ;

one or more heteroatom donor ligands bonded to the nanoparticles; and

a solvent,

wherein

Cu is copper;

O is oxygen; and

x and y are numbers having a ratio that is equal to the ratio of the average number of Cu atoms to the average number of O atoms in the nanoparticles, wherein the number of Cu atoms is from about 10 to about $5x10^{10}$ atoms and the number of O atoms is at least about 0.01 times the number of Cu atoms.

38. The copper oxide-containing solution of claim 37 wherein the heteroatom donor ligand is derived from decanoic acid and the solvent is hexane.

39. The copper oxide-containing solution of claim 37 wherein the heteroatom donor ligand is 2,2'-bipyridine and the solvent is a polar solvent.

40. The copper oxide-containing solution of claim 37 wherein the solvent comprises a component selected from the group consisting of methanol, ethanol, 1-propanol, isopropanol, 1-butanol, acetone, dichloromethane, and ethylene glycol.

41. The copper oxide-containing solution of claim 37 wherein the heteroatom donor ligand is 2,2'-bipyridine to which long chain alkyls have been attached and the solvent is a nonpolar solvent.

42. A method for making metal oxide-containing nanoparticles, the method comprising:

reacting a metal ion in solution with a heteroatom donor ligand to form a metal complex; and

reducing the metal complex with a reducing agent to form the metal oxide-containing nanoparticles.

43. The method of claim 42 wherein the metal ion solution is formed by dissolving a metal salt in a solution.

44. The method of claim 42 wherein the mole ratio of metal ion to ligand is from about 0.05 to about 20.

45. A method for making copper oxide-containing nanoparticles, the method comprising:

1) reacting CuX_2 with a heteroatom donor ligand to form a copper complex; and

2) reacting the copper complex with a first reducing agent to form the copper oxide-containing nanoparticles, wherein X is a metal ion counterion.

46. The method of claim 45 wherein X is selected from the group consisting of halide, nitrate, phosphate, perchlorate, formate, acetate, borate, hydroxide, silicate, carbonate, sulfite, sulfate, nitrite, phosphite, hydrates thereof; and mixtures thereof.

47. The method of claim45 wherein the one or more heteroatom donor ligands include compounds containing an oxygen or nitrogen atom that is capable of acting as an electron-pair donor to form a bond to the surface of the nanoparticles.

48. The method of claim 45 wherein the one or more heteroatom donor ligands are selected from the group consisting of alkyl amines, pyridine, 2,2'-bipyridine, pyrrole, pyrazole, imidazole, triazole, tetrazole, nitriles, carboxylic acids, carbonates, nitrates, nitroalkanes, nitroarenes, hydroxamic acids, ketones, aldehydes, and esters.

49. The method of claim 45 wherein the copper oxide-containing nanoparticles include a mixture of copper atoms in different oxidation states.

50. The method of claim 49 wherein the different oxidation states are 0, +1, and +2.

51. The method of claim 45 wherein the first reducing agent is sodium borohydride, lithium aluminum hydride, molecular hydrogen, sodium metal, zinc metal, magnesium metal, aluminum metal, or hydrazine.

52. The method of claim 45 wherein the copper oxide nanoparticles comprise Cu_2O.

53. The method of claim 45 wherein the copper oxide nanoparticles have a diameter from about 1 nm to about 100 nm.

54. The method of claim 45 wherein the copper oxide nanoparticles have a diameter less than about 20 nm.

55. The method of claim 45 wherein the copper oxide nanoparticles are amorphous or crystalline.

56. The method of claim 45 further comprising:

3) heating the copper oxide-containing nanoparticles to a sufficiently high temperature to form copper metal.

57. The method of claim 45 wherein the copper oxide nanoparticles are heated to a temperature of at least 200 °C.

58. The method of claim 45 further comprising contacting the copper oxide nanoparticles with a second reducing agent.

59. The method of claim 58 wherein the second reducing agent is selected from the group consisting of molecular hydrogen, alcohols, amines, or mixtures thereof.